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"HEART DAMAGE" IN BALED JUTE

THE ROYAL COMMONWEALTH INSTITUTE

BY

R. S. FINLOW, B.Sc., F.I.C., F.C.S

Fibre Expert to the Government of Bengal

MAR 4 - 1968
UNIVERSITY OF TORONTO

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

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PREFACE.

As stated in the body of this report, the work on which it is based was commenced in 1907, in collaboration with Messrs. Cross and Bevan of London. "Heart damage" is, however, linked up with the question of watering of jute and was therefore one of the reasons for the outcry, from 1901 onwards, regarding the alleged deterioration of jute. The latter was the immediate cause of the writer's appointment, in 1904, to make a special study of fibres.

The attention given to the investigation into "heart damage" has necessarily been intermittent, owing to the pressure of more urgent demands on my time; but it was also advisable that no hasty conclusions should be drawn in dealing with a subject which is often the cause of commercial disputes.

I have to express my indebtedness to the Hon'ble Sir A. Birkmyre (Messrs. Birkmyre Bros.), Mr. Brackenridge (Messrs. J. C. Duffus & Co.), Mr. D. L. Millar (Messrs. D. L. Millar & Co.), and Mr. P. E. Suttie (Messrs. Sinclair Murray & Co.) for kindly advice and for reading through the manuscript.

I am also indebted to Dr. Butler, Imperial Mycologist, Pusa, for identifying the mould *Aspergillus fumigatus*, Fres., and for his note on the same, which is published herewith as an appendix.

My best thanks are due to Mr. George Macdonald of Bara, Champaran, Bihar, for the use of his press in the *kutcha* (3½ maunds or 280 lb.) baling test. I also wish to acknowledge with many thanks the help given by Mr. H. M. Shircore (Messrs. Sarkies & Co. of Narayanganj), not only in lending the firm's press for all three *pucca* (5 maunds or 400 lb.) baling tests, but also in the considerable personal trouble to which he went in order to ensure the success of the tests.

My Assistant, Mr. N. C. Basu, M.Sc., has done valuable work in the more recent stages of the investigation.

R. S. F.

DACCA:
3rd July, 1917.

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"HEART DAMAGE" IN BALED JUTE.

BY

R. S. FINLOW, B. Sc., F.I.C., F.C.S.,

Fibre Expert to the Government of Bengal.

[Received for publication on the 5th Ju'y, 1917.]

PART I. INTRODUCTORY.

THE more recent work on "heart damage" arose out of correspondence, 1905, between Messrs. Cross and Bevan of London, and the author of this paper regarding the natural moisture content of jute.

Previous references to the subject seem to be confined to the publications of Messrs. Cross and Bevan. In 1880, in a paper on the chemistry of bast fibres, read before the Owen's College (now Manchester University) Chemical Society, these authors, in dealing with the action of dilute acids on jute, describe "an interesting species of fermentation, which takes place when masses of jute are allowed to lie in a damp state, in consequence of which the fibre undergoes a similar dissolution to that which is induced by hot acids.....". The sample examined "contained as much as 10 per cent. of matter soluble in water....." and, "with a 1 per cent. solution of caustic soda, as much as 23 per cent. of the weight of the fibre was removed in solution.....". "The decomposition which had taken place resembled, therefore, that which is effected by hot dilute acids in every particular with the exception that, in the latter case, traces only of the aromatic constituents are rendered soluble."

Messrs. Cross and Bevan, in 1882 (*Journal of the Chemical Society*, XLI, 1882, page 92), describe the examination of a sample of damaged jute which yielded an aqueous extract which was brown, "astringent to the taste, and, at the same time, strongly acid to test paper."

Subsequently no further progress seems to have been made until 1907 when, in collaboration with Messrs. Cross and Bevan, the writer commenced a practical investigation into the conditions necessary for the production of

"heart damage" in baled jute. The series of experiments was concluded in due course, and in May, 1908, a report[1] was presented to His Majesty's Secretary of State for India by Messrs. Cross and Bevan. Since then the writer has carried the investigation further, and the present communication is the outcome of the latter work.

Characteristics of "Heart Damage."

The deterioration in jute known as "heart damage" is so called, because its effects appear first in the centre of the bale of fibre in which it takes place. It is a phenomenon which has long been familiar to members of the jute trade, by whom its incidence is universally ascribed to the presence of an undue proportion of water in the fibre. "Heart damage" is usually associated with baled jute; but it is important to remember that the storage of a sufficient bulk of unbaled jute in a damp condition will produce an exactly similar form of deterioration. For instance, at country markets or collecting centres, in wet weather, it is common to see loose jute beginning to heat. Such jute is always damp, and a rise in the temperature of the mass is recognized as a warning that the jute must be dried at once if a marked weakening, or even more serious damage to the fibre, is not to ensue. "Heart damage" is, however, the term usually applied in reference to deterioration of baled jute, and especially to the deterioration of *pucca*,* *i.e.*, the large 5-maund, bales, in which form the whole of the jute which goes to foreign markets is exported. It is said that 3 per cent. of the total imports of jute into Dundee in 1906 were rejected on this account.

It will be shown later that "heart damage" is never met with in good dry fibre, and that it only takes place in the presence of excessive moisture, *i.e.*, a moisture content to which it would be practically impossible for a sample of fibre to attain by absorption from the atmosphere under the most favourable conceivable conditions. Further, the percentage of moisture which suffices for the production of damage seems to vary inversely as the tightness with which the fibre is packed. Thus a small loose heap of jute would probably require nearly 50 per cent. of water for damage to take place. In a larger heap the necessary moisture content would be proportionately less in the region of greater pressure, and in a *pucca* bale only about 25 per cent. seems to be required. In a *kutcha* bale, in which the pressure is less than

[1] Report by Messrs. Cross and Bevan on investigations of jute fibre in relation to "heart damage" of baled jute, India Office, 1908.

* A *kutcha* (Hindi, imperfect) bale commonly weighs 3½ maunds or 280 lb., and is less tightly pressed than the *pucca* (thorough) bale which weighs 5 maunds or 400 lb. There are, however, other *kutcha* bales, weighing from one maund to three maunds each.

in a *pucca* bale, decidedly more than 25 per cent. of water seems to be necessary in order that damage may take place.

A reasonable explanation of this seems to be that the damage takes some time to develop, and that the loss, by evaporation, of the water required for its progress, is proportionately prevented by tight packing, which would also tend to produce a more even and permanent distribution of the water throughout the mass. It was at first thought that the greater exclusion of air, also due to tight packing, might facilitate the development of the damage ; but a biological investigation into the latter, now in progress, does not support this view ; on the other hand, there are indications that the purely physical effect, on the fibre, of the great pressure employed in a *pucca* (400 lb.) bale may help the incidence of the damage.

In a single *pucca* (400 lb.) bale of sufficiently damp jute, the temperature begins to rise after a period varying from about 10 days to six weeks (according to the temperature of the air at the time of, and subsequent to, baling), and continues to do so gradually, if there is sufficient moisture, until the thermometer reaches about 40° C. (104° F.), where it may remain practically constant over a period of many weeks. During this period the damage is taking place, and a fall in the temperature indicates that the action is slackening, or has ceased, whether on account of completion or because of insufficient moisture.

The appearance of the interior of a bale which has suffered damage differs considerably according to the amount of water absorbed by the fibre before baling. If the water percentage is below a certain point, the temperature will not rise ; but the contents of the bale, on opening, will have a musty smell and the fibre will be weakened, more or less in the proportion in which the water percentage is sufficient for complete damage : typical " heart damage " does not occur under these conditions. When the moisture percentage exceeds the point mentioned above, a definite and pronounced rise of temperature, accompanied by typical " heart damage", ensues, and the fibre completely loses its tensile strength. When the percentage of water is not too high, very little discoloration accompanies the damage, and in these circumstances the interior of the bale often has a quite strong winy smell, which is an indication to what great length the decomposition has proceeded. With a still higher moisture percentage the fibre becomes decidedly wet, and the damage finally approximates to putrefaction, which is accompanied by great discoloration.

Very often it is possible to detect evidence of organic growth on the damaged fibre : for instance, a white beady growth seems characteristic ; but

this is often, especially in excessively watered bales, masked by the black spores of a mould—*Aspergillus fumigatus*, Fres. The latter is probably not one of the necessary agents causing the damage, but rather seems to develop on the products of decomposition (*vide* Appendix I).

There can be no doubt at all that "heart damage" is the result of biological action, and an investigation into its cause has already resulted in the production, in the laboratory, with bacterial cultures taken from a damaged bale, of all the characteristic phenomena of "heart damage." It is intended to make this latter investigation the subject of a later communication.

We have seen that "heart damage" involves a radical physical change in jute; for instead of remaining a fibre of considerable tensile strength it becomes a spongy, brittle mass which can easily be rubbed into a fibrous powder. "Heart damaged" jute is, therefore, entirely useless for spinning purposes.

The chemical changes produced are equally great, the most important being—

(1) Great diminution of cellulose content.

(2) A far larger proportion of the weight of the fibre becomes soluble in water and in simple chemical reagents.

(3) Diminution in the yield of furfurol on boiling the fibre with hydrochloric acid.

The microscopic appearance of a damaged sample of jute is not so striking as the profound chemical changes might lead one to believe. Fragments of damaged fibre indeed show very little sign of any great change, beyond the fact that the bundles of ultimate filaments, whose aggregation forms the fibre, are seen to be broken across at right angles to their longitudinal axes. This is, of course, only another way of describing the complete loss of tensile strength already referred to. Even on boiling with alkali, damaged fibre shows comparatively little sign of change, although the chemical analysis may show that one-third of its cellulose has been dissolved away. Such a result could only have been achieved in sound fibre by prolonged acid hydrolysis. Under the microscope the ultimate fibres in the damaged bundles are apparently transversely marked in a large number of places; on the other hand, a sample of sound jute, brought to a similar phase by chemical treatment, does not exhibit these markings, which would appear to be fractures.

It is worth recording, as bearing on the apparently easier incidence of "heart damage" in baled jute (*vide* p. 35), that fibre which has been baled frequently shows, on examination under the microscope, transverse markings,

which are much more rarely visible in fibre which has not been baled. It is a well-known fact that an experienced person can tell, by mere cursory examination, whether a sample of fibre has been baled or not. This distinction is possible owing to the " kinks " caused by the great pressure in baled fibre, and it is reasonable to suppose that, in this case, the transverse markings are only the microscopic aspect of the effect of pressure.

PART II. BALING TESTS.

1. Tests with Kutcha Bales.

Four sets of baling tests have been carried out, the first of them being done, as already explained, in collaboration with Messrs. Cross and Bevan. Mr. George Macdonald of Bara, Champaran, Bihar, to whom we are much indebted, lent his press for this test, in which only *kutcha* (3½ maunds or about 280 lb.) bales were used. Six of the bales were made up from a large, uniform bulk of fibre, with sufficient added water to bring the percentage of moisture up to approximately 30 per cent. Sugar, as typifying easily fermentable matter, as well as certain other chemicals, was also added to some of the bales, which were shipped to London in the ordinary way. On being opened in London several months later, it was discovered that, although some of the fibre was weakened, no serious damage had taken place in any of the bales, the contents of which were ultimately sold as first class fibre. No conclusion could, therefore, be drawn regarding the amount of moisture which is necessary for the incidence of "heart damage," excepting that it is over 25 per cent., and probably over 30 per cent. for bales of the size and tightness of packing in question; however, the following inferences, among others, seemed justifiable, always remembering that they apply only to the particular size and type of bale used (*vide* report *loc. cit.*).

1. "This excessive moisture" (approximately 25 per cent.), *per se*, causes no evident damage nor lowering of the quality of the fibre.

2. "The presence of easily fermentable matter, associated with excessive moisture, does not constitute a combination necessarily dangerous to the fibre."

3. Some "mould and bacteria growths may develop on the fibre without causing deep-seated changes of the fibre substance."

4. "The specific chemical features of 'heart damage' are profound changes in the fibre substance, as a complex, without correspondingly large changes in the constitution of the approximate constituent groups."

5. It is considered that the hydrolytic changes taking place in the cellulose constituent of the fibre, resulting in the formation of "nutrient or assimilable matter available for living organisms, are an important object of research in

agricultural chemistry.....and of positive economic value to other industries."

2. Tests with Pucca Bales.

The baling in the remaining tests was done by Messrs. Sarkies & Co., of Narayanganj, and we are much indebted to them for the use of their *pucca* press on these occasions.

The fibre for all bales in each test came from the same bulk ; so that each bale in any test was comparable, as far as possible, with any other.

For the purpose of adding the water, the fibre was spread out on the wooden floor of the press room, and the required amount of water was added in a fine spray. The fibre was turned over once during the spraying, to insure even application of the moisture, and baling was done immediately after the addition of water, so as to prevent loss by evaporation. As it was necessary to register any subsequent rise of temperature which might take place in the bale the following arrangement was made : pieces of strong iron tube, 2 inches in diameter, and approximately 1 foot long, were corked at one end, and then packed as tightly as possible with sand, after which the other end was corked. As each bale was being made up one of these tubes was introduced ; so that one end of the tube reached about to the centre, while the other end of the tube was flush with the outside of the bale. The sand helped to prevent the tube from being flattened out when the pressure of two tons to the square inch was applied to the bale, and sufficient of it was afterwards scraped out to allow a maximum thermometer to be completely immersed in the tube, the outer end of which was then closed with a tight wad of cotton-wool. In this way it was possible to register, with some accuracy, the maximum temperature attained by the centre of the bale.

Method of estimating moisture.

A weighed portion of moist fibre is placed in an oven at 105° C. (221° F.), and dried until it ceases to lose weight. The loss of weight, multiplied by 100 and divided by the original weight of damp fibre, gives the percentage of moisture in the sample : thus :—

Weight of damp fibre	..	10 grm.
Loss of weight ,,	..	1 ,,
Then true percentage of moisture $\frac{100 \times 1}{10}$	..	10 per cent.

It is important to contrast this method with that which usually obtains in trade circles. The latter is described by Mr. Suttie as follows :—"Dry

the jute, over bamboos, for several hours, in the sun; store overnight in a godown* and weigh in the morning. The difference between the weight taken before drying, and the weight the following morning would indicate the real percentage of artificial moisture, the assumption being that any of the natural moisture taken from the jute is recovered from the atmosphere overnight." It is obvious that this treatment cannot drive off all the moisture from the fibre, which always retains a certain proportion, varying from about 5 per cent. to 15 per cent., according to the thoroughness of the treatment. The laboratory method, which is similar to that used in conditioning houses in Europe, secures complete desiccation of the fibre, and the results obtained by it are correct, and always higher, by from about 5 per cent. to 15 per cent., than those given by the trade method. To convert the laboratory moisture percentage into those obtained by the trade method, it would, therefore, be necessary to subtract from 5 per cent. to 15 per cent. Thus if the moisture content, as determined in the laboratory, is 20 per cent., the trade figures would be between 5 per cent. and 15 per cent.

First Series of Pucca Baling Tests.

The main object of this series of tests with *pucca* bales was to make sure of producing "heart damage"; and 25 per cent. of water, making 35 per cent. with the original 10 per cent. contained by the fibre, as representing a quantity certain to secure this object, was therefore added to one bale. The contents of a second bale were made up to about 29 per cent., as it seemed probable that this moisture content would be just below, or just on, the lower limit at which damage takes place. A further object was to show that good dry jute does not suffer "heart damage", and for this purpose a bale was made up without the addition of water, *i.e.*, containing 10 per cent. of moisture.

The quality of fibre used in all the bales was "Threes", guaranteed to contain 75 per cent. sacking warp and the respective quantities of fibre and added water were calculated as follows:—

$$\text{Absolute weight of water in a bale} = \frac{\text{Weight of moist fibre} \times \text{percentage of water}}{100}$$

If the original fibre contains 10 per cent. moisture and it is required to make the percentage up to 29 per cent:—

By the above formula, moisture percentage	.. 29 per cent.
Total weight of moist fibre in bale ..	.. 400 lb.

* Warehouse.

Therefore total weight of water in a bale $\frac{400 \times 29}{100}$, *i.e.*, 116 lb.

Therefore absolutely dry fibre .. .. 284 ,,

but the original fibre contains 10 per cent. of moisture, *i.e.*, $\frac{284}{9}$, *i.e.* .. .. 31·6 ,,

Therefore weight of water to be added to bring moisture percentage up to 29 per cent. is 116 minus 31·6, *i.e.* .. .. 84·4 ,,

and the weight of fibre containing 10 per cent. of water to be taken would therefore be .. .. 315·6 ,,

Similarly for 35 per cent. of moisture the weight of water to be added is $\frac{400 \times 35}{100}$ minus $\frac{260}{9}$ .. 111 ,,

and the weight of fibre containing 10 per cent. of water would therefore be .. .. .. 289 ,,

The final contents of the bales were as detailed in the following table :—

Bale No.	Original fibre containing 10 per cent. moisture	Absolutely dry fibre	Water	Weight of water added to original fibre	Total weight of water in bale	Final percentage of water in bale
	lb.	lb.	lb.	lb.	lb.	Per cent.
1	400	360	40·0	...	40	10
2 ...	316	284	31·6	84·4	116	29
3 ...	289	260	29·0	111·0	140	35
4 ...	289	260	29·0	111·0	140	35

These bales were made up on May 21st, 1912, and they were opened on September 15th, 1912, *i.e.*, after an interval of 116 days. The following notes were made at the time of opening the bales :—

Bale No. 1. *Unwatered jute.*

This bale was absolutely normal and showed no signs of any damage. Its weight had increased by 3 lb., which is accounted for by its prolonged exposure to the damp atmosphere of the monsoon. The maximum thermometer in the interior of the bale, which was at 86° F. at the time of baling, showed that no rise of temperature had taken place.

Bale No. 2. *Jute to which* 19 *per cent. of water had been added, i.e., containing* 29 *per cent. moisture.*

This bale had lost 20 lb. in weight, and the thermometer, which registered 86° F. at the time of baling, showed a maximum of 98° F. or a rise of 12° F.

The bale had not burst: but the rise in temperature indicated a considerable amount of fermentation. The contents of the bale, which were still warm on opening, were uneven: over one half of the fibre was perfectly strong, but the remainder was all more or less damaged, some of it badly so. Although the damage seemed to be rather unevenly distributed, the chief deterioration was in the centre. There were no signs of the black mould spores so characteristic of bales Nos. 3 and 4.

Bale No. 3. Containing 35 per cent. of water.

This bale had burst and the fibre was so damaged that the bale could not be weighed. The thermometer showed a maximum temperature of 101° F. or a rise of 14° F. The contents of the bale had a musty smell and were badly damaged. When rubbed with a hard body a black line was left on the fibre, this probably being due to bursting of black mould spores. The temperature was not nearly high enough to produce carbonization of the fibre.

N.B. It has since been established that the blackening is due to mould spores; but the mould appears only to feed on the decomposition products of the damage and does not seem to be an agent producing it (*vide* Appendix I).

Bale No. 4. Containing 35 per cent. of water.

This bale had also burst, the maximum temperature was also 101° F., and the contents of the bale were similar in all respects to those of No. 3, being completely damaged.

General Remarks.

These experiments were only preliminary ones in the attempt to determine the limit of moisture content of the fibre beyond which "heart damage" is likely to occur. It is plain that 35 per cent. is a long way beyond this limit.

The result in the case of bale No. 2 is less certain; but it appeared that the point at which definite damage can take place is probably rather below 29 per cent. of water. On the other hand, it is very obvious that good dry fibre does not suffer damage when baled, which supports the universal opinion of the members of the jute trade.

The rise of temperature in the damaged bales is very typical of biological action.

Second Series of Pucca Baling Tests.

In this series it was decided to use 29 per cent. water as a maximum, and also that the moisture content of other bales should diminish by increments of about 2 per cent. It was expected that the bales containing most water would suffer, and that those containing least would not; but it was hoped one of the bales might be just damaged, while the one containing the next lower water percentage would not show marked signs of deterioration.

It was hoped also, in this series, to throw light on a point raised by a member of the jute trade, *viz.*, whether a bale originally containing dry jute would, after wetting of the exterior of the bale, as by complete immersion for a short time, suffer "heart damage," even if the fibre in the centre of the bale is not wetted during the period of immersion. A further object was, if possible, to throw some light on the production of "ship damage", which is fully discussed on pp. 57—59. For this purpose a bale containing 4 maunds 38 seers of dry jute was immersed in water for 45 seconds, after which it weighed 5 maunds 23 seers, having taken up 25 seers, or roughly about 50 lb. of water. The total moisture content of the fibre was then roughly 25 per cent.

The whole of the jute used was one sample, *viz*, "Threes" containing 70 per cent. warp; but occasional hanks of *bogi* (fibre of *C. olitorius*) were to be found. The original moisture content was 16 per cent.

Bale No.	Original fibre containing 16 per cent. moisture	Consisting of		Weight of water added to original fibre	Total weight of water in bale	Final percentage of water in bale
		Absolutely dry fibre	Water			
	lb.	lb.	lb.	lb.	lb.	Per cent.
1 ...	401	336	64	...	64	16·0
2 ...	365	307	58	35	93	23·0
3 ...	354	297	57	46	103	26·0
4 ...	336	282	54	64	118	29·5
5 ...	346	291	55	54	109	27·0
6 ...	406	341	65	50	115	25·0

The bales were made up on the 9th February, 1913, and they were opened on the 29th March, 1913; *i.e.*, only about 6 weeks later. The following observations were made at the time of opening.

Bale No. 1. *No added water,* 16 *per cent. natural moisture.*

Interior of bale quite cool, fibre fairly dry to the feel and certainly undamaged; water content of fibre at the time of opening the bale 16 per cent.

Bale No. 2. Total water content 23 per cent.

Fibre damp with a musty smell, and rather weaker than that of No. 1; but not sufficiently so to affect its market value. The interior of the bale was cool. Water content of fibre at the time of opening the bale 20·83 per cent.

Bale No. 3. Total water content 25·6 per cent.

Fibre damper and had a decidedly stronger smell than that of No. 2; the small amount of *bogi* did not feel so damp. The contents of the bale had not deteriorated sufficiently to affect the value of the fibre, and the interior of the bale was cool. Water content of fibre at the time of opening the bale 23·1 per cent.

Bale No. 4. Total water content 29·5 per cent.

The interior of the bale was hot, *i.e.*, 95° F. (35° C.), the temperature having risen from 86° F. (29·5° C.). The fibre had a strong musty smell and was badly "heart damaged" in the centre. Water content of fibre at the time of opening the bale 24·8 per cent.

Bale No. 5. Total water content 27 per cent.

Bale quite cool in interior; fibre had a strong musty smell and damp feel; but though decidedly weakened there were no marked signs of damage, and the value of the fibre was not seriously affected. A small amount of *bogi* in the bale was not weakened so much as the fibre of *C. capsularis*. Water content of fibre at the time of opening the bale was 23·8 per cent.

Bale No. 6. Dry fibre immersed in water for 45 seconds after baling.

This bale was quite cool in the centre, but the outside fibre at a depth of about 3 inches was decidedly damaged to such an extent as to affect its value seriously.

General Remarks.

This test confirmed the former one in placing the point at which "heart damage" takes place below 30 per cent., but, as the next series will show, the deterioration can take place with a distinctly lower percentage of moisture than 30 per cent., provided sufficient time and a suitably high initial temperature be given. It seems possible in fact that bale No. 5 certainly, and probably, to a less extent, bale No. 3 also would have suffered serious damage, if a longer period than 6 weeks had been allowed. In this case it has to be noted that the baling was done at the coldest period of the

year, and that the temperatures to which the bales were exposed during the whole of the first month were very low, as the following readings, kindly taken by Mr. Shircore, show :—

Temperature of bales in degrees Fahrenheit.

Date of baling	No. 1	No. 2	No. 3	No. 4	No. 5
11th February, 1913 ...	80°	79°	82°	80°	81°
19th February, 1913 (one week after baling)	71°	76°	76°	76°	76°
25th February, 1913 ...	78°	76°	80°	80°	80°
3rd March, 1913	72°	70°	74°	74°	74°

It has been ascertained, in the course of the bacteriological investigation already referred to, that the optimum temperature for the growth of the organisms causing " heart damage " probably lies somewhere between 100° F. (38° C.) and 105° F. (41° C.), and that any marked diminution of temperature depresses their activity to an extraordinary extent. In view of this knowledge, which we did not at that time possess, it is not surprising that, at the low temperatures recorded above, no very serious change took place in the majority of the bales.

It has already been noted that the fibre used in these tests contained a very small amount of the fibre of *C. olitorius*, known variously to the trade as *bogi*, *tosha*, *deopat*, or *desi* jute, and there were indications that the latter is not so liable to suffer damage as the fibre of *C. capsularis*. No definite conclusions can be drawn from such fragmentary evidence ; but the point seems worth following up. It is also highly probable that different qualities of the same kind of fibre would vary considerably in their susceptibility to damage under given conditions of moisture ; for instance, a slightly over-retted fibre would probably be more likely to undergo " heart damage " than a good sound sample. Similarly it might be anticipated that a soft fluffy fibre would be less resistant than hard jute. These, however, are only speculations, and further work is obviously needed to obtain more definite information.

Third Series of Pucca Baling Tests.

The last series had indicated that 29 per cent. of moisture was sufficient to produce " heart damage " in less than seven weeks when the temperature during the first month was exceptionally low. It was therefore fairly certain that, given a longer time, decidedly smaller quantities of water would prove sufficient for the development of the deterioration. For this reason it was decided to commence with 27 per cent. as the moisture content of the dampest

bale in the series, and the remaining four bales contained respectively 26 per cent., 25 per cent., 24 per cent., and 23 per cent. of water.

The following table gives detailed information regarding weights of jute, quantities of water added, etc. :—

Bale No.	Original fibre containing 10·4 per cent. moisture used	Consisting of		Weight of water added to original fibre	Total weight of water in bale	Final percentage of water in bale
		Absolutely dry fibre	Water			
	lb.	lb.	lb.	lb.	lb.	Per cent.
1 ...	344·0	308	35·80	56·2	92	23
2 ...	339·3	304	35·30	60·7	96	24
3 ...	334·8	300	34·80	65·2	100	25
4 ...	330·4	296	34·36	69·6	104	26
5 ...	325·9	292	34·00	74·0	108	27

The bales were made up on the 12th March, and they were opened on the 23rd June, 1915. It should be mentioned that, owing to the pressure during baling, a small quantity of water was squeezed out from bales containing 25 per cent. of water and over ; the amount thus lost was too small to be of any consequence ; but it indicates that, in a *pucca* bale containing 25 per cent. moisture, all air space is completely filled with water.

The following table shows the respective temperatures of the bales on three separate dates after baling :—

Temperatures of the bales in degrees Fahrenheit.

Date	No. 1	No. 2	No. 3	No. 4	No. 5
17th March, 1915 (6 days after baling)	86°	82°	86°	86°	86°
3rd May, 1915 (6½ weeks after baling)	84°	86°	104°	88°	102°
26th June, 1915 (14 weeks after baling and at the time of opening)	86°	87°	104°	104°	104°

The following notes were made on the spot at the time of opening the bales :—

Bale No. 1. *Total moisture content* 23 *per cent.*

Fibre, moist to the feel, has lost the typical smell of jute and had a musty odour, though not a strong one. There were isolated patches of black spotted fibre, looking like agglomerations of spores ; in these places the fibre is distinctly weak, but elsewhere there is no serious diminution of strength.

Bale No. 2. Total moisture content 24 per cent.

Fibre decidedly weaker than No. 1, even in places where there is no visible growth ; but the failure of the temperature to rise shows that no actual " heart damage " has taken place. There was comparatively little of the black mould growth, although the fibre is weak ; and it has still to be proved that the mould is one of the causes of the damage. The fibre has a decidedly stronger musty smell than that of bale No. 1.

Bale No. 3. Total moisture content 25 per cent.

The fibre in the centre of this bale is completely damaged, being absolutely weak, as would be expected from the marked rise in temperature which has taken place in the bale. The temperature is moreover still at its maximum, showing that, even after 14 weeks, the fermentation causing the damage is still actively proceeding. The black mould was present everywhere, but not in large quantity, and a white beady growth was also evident. In the badly damaged portions of the bale the musty smell had given place to a distinct winy odour.

Bale No. 4. Total moisture content 26 per cent.

This bale was even more completely damaged than No. 3. The fibre was very weak : and there was comparatively little of the mould but correspondingly more of the white growth ; moreover the smell was not musty but rather winy throughout. The high temperature of the bale shows fermentation to be still in active progress.

Bale No. 5. Total moisture content 27 per cent.

Bale completely damaged : very like No. 4 : mould spores very common but white growth also present with the same winy smell.

General observations on the baling tests.

Excepting in the bales containing 35 per cent. water, none of the fibre in any of the last three series of tests has been seriously discoloured : this is particularly true of the fibre in the bales in the third series, which suffered " heart damage " with only 25 per cent. to 27 per cent. of water. The result of the latter series of tests is to confirm the conclusion drawn from the second series, *viz.*, that given a higher temperature and a longer time, a smaller percentage of water than 29 per cent. would suffice to produce " heart damage." This has actually proved to be the case, and, although, judging from the time at which a rise of temperature began, the contents of bale No. 4

might have been more resistant to the damage than Nos. 3 and 5, the ultimate results were very concordant. This, and the smallness of the increments of moisture, justify us in concluding that "heart damage" is likely to occur in *pucca* bales when the total moisture content, estimated by drying the fibre at 221° F. (105° C.) as previously described, exceeds 25 per cent. The latter figure would probably correspond to something between 10 per cent. and 15 per cent. if, as is common in trade circles, the moisture were only estimated by sun-drying (*vide* pp. 39-40).

PART III.—LABORATORY EXPERIMENTS.

It now became necessary to ascertain, by experiment, the maximum percentage of moisture which can be taken up by jute fibre, when exposed to a damp atmosphere of known humidity, for a definite time and at a constant temperature, and to compare the result thus obtained with the approximate lowest percentage moisture content which the baling tests indicated as sufficient for the development of "heart damage." In this way definite information was obtained regarding the possibility of the occurrence of "heart damage" in jute, which, having been properly dried at the time of extraction, has subsequently only been subjected to legitimate atmospheric moisture conditions. The latter, it is hardly necessary to state, do not include exposure to rain or to night dews.

In discussing this aspect of the question, it is advisable first of all to give a definite meaning, in percentage figures, to the terms "normal moisture content," "sound dry jute," and "air dry jute", and in this connection the following quotation will be found apposite :—

N.B. It is perhaps necessary to repeat here what was said on page 39, *viz.*, that all moisture percentages quoted in this paper have, unless a definite statement is made to the contrary, been obtained by drying the sample in an oven at, or above, the temperature of boiling water (100° C. or 212° F.). These percentages are therefore higher by 10 per cent., more or less, than those commonly used in trade circles, which are obtained by drying in a hot sun instead of in an oven.

TABLE I.*

No. of samples	Date of experiment	Source of fibre	Percentage of moisture	Remarks, *i.e.*, notes sent with the samples
1	14th Nov., 1904	Through Messrs. Ralli Bros. of Serajganj	11·22	Described as "dry."
2	Ditto	Ditto	10·94	
3	Ditto	Ditto	10·88	
4	Ditto	Ditto	10·95	

* "General Report on Jute in Bengal for 1904-5," by R. S. Finlow.

TABLE I—*concld.*

No. of samples	Date of experiment	Source of fibre	Percentage of moisture	Remarks, *i.e.*, notes sent with the samples
22	20th Nov., 1904	Through Messrs. Landale and Clark of Serajganj	15·06	"Dry jute."
26	Ditto	Ditto	15·10	"Dry."
28	3rd Dec., 1904	Through Messrs. Ralli Bros. of Serajganj	11·33	"Northern Bengal dry."
29	Ditto	Ditto	12·81	"Serajganj dry."
31	Ditto	Ditto	11·21	"Dowrah dry."
33	Ditto	Ditto	16·88	"Desi dry."
36	Ditto	Ditto	15·47	"Dacca dry."
39	Ditto	Camperdown Press, through Assistant Director of Agriculture, Bengal	12·11	"Narayanganj dry."
43	Ditto	Ditto	11·08	"Sound dry."
41	Ditto	Ditto	20·85	"Little wet."
60	Ditto	Central Jute Mills, through Assistant Director of Agriculture, Bengal	15·09	"Sound."
66	Ditto	Ditto	12·01	"Sound dry, Dacca.'
68	Ditto	Ditto	11·14	"Sound dry, Rangpur."
70	Ditto	Ditto	13·45	"Good sound jute, Northern Bengal."
73	Ditto	Ditto	11·95	"Good sound jute, Khulna."

"The following results[1] were obtained from samples of damp jute collected at the same time and places as the above: they are included for information as well as by way of contrast. All the samples were taken in the open market where they were exposed for sale."

TABLE II.

No. of samples	Date of experiment	Source of fibre	Percentage of moisture	Remarks, *i.e.*, notes sent with the samples
5	14th Nov., 1904	Through Messrs. Ralli Bros. of Serajganj	29·21	
6	Ditto	Ditto	31·33	Described as "wet."
7	Ditto	Ditto	33·80	
8	Ditto	Ditto	30·46	
9	Ditto	Ditto	54·03	
10	Ditto	Ditto	32·62	"Wet and sanded."
11	Ditto	Ditto	45·26	*N.B.* Sand was not
12	Ditto	Ditto	43·98	estimated.
13	Ditto	Ditto	24·24	
14	Ditto	Ditto	37·74	"Damaged."
15	Ditto	Ditto	34·22	
16	Ditto	Ditto	24·77	
18	19th Nov., 1904	Ditto	55·17	These four samples
19	Ditto	Ditto	54·21	were selected as
20	Ditto	Ditto	46·32	being particularly
21	Ditto	Ditto	49·78	bad instances of watering.

[1] Loc. cit.

TABLE II.—*concld.*

Number of samples	Date of experiment	Source of fibre	Percentage of moisture	Remarks, *i.e.*, notes sent with the samples
23	20th Nov., 1904	Through Messrs. Landale and Clark of Serajganj	48·42	
24	Ditto	Ditto	42·19	"Wet."
25	Ditto	Ditto	33·64	
27	Ditto	Ditto	35·41	
30	3rd Dec., 1904	Through Messrs. Ralli Bros. of Serajganj	40·77	"Northern Bengal wet."
32	Ditto	Ditto	38·29	"Dowrah wet."
34	Ditto	Ditto	38·22	"Serajganj wet."
35	Ditto	Ditto	48·37	"Desi wet."

"The following samples were sent as being typical of dry fibre, in order that some idea might be obtained of the amount of moisture absorbed by jute fibre from the atmosphere in the rainy season. They were collected during the latter part of September, 1905, when the humidity, as well as the temperature, being high, the amount of moisture vapour present in the air would be correspondingly great."

TABLE III.

Number of samples	Date of experiment	Source of fibre	Percentage of moisture	Remarks, *i.e.*, notes sent with the samples
75	8th Oct.	Through Messrs. Landale and Clark of Serajganj	14·2	...
76	Ditto	Ditto	15·7	...
77	Ditto	Ditto	15·4	...
78	Ditto	Ditto	11·8	
79	Ditto	Ditto	13·0	...
80	Ditto	Ditto	15·7	...
81	Ditto	Ditto	15·3	...
82	Ditto	Ditto	14·6	...
83	Ditto	Ditto	13·6	...
84	Ditto	Ditto	12·4	...
85	Ditto	Ditto	12·1	...

"The results given below are for samples which had been kept at Pemberandah (Bihar) for some time. When the last two estimations in the table were made, the weather was hot and dry. They show, by comparison with the figures in the previous table, that the amount of moisture in a genuine sample of fibre varies considerably according to the temperature and hygroscopic condition of the atmosphere."

TABLE IV.

Sample	Date	Percentage of moisture
A	5th February, 1905 ..	10 91
B	Ditto ...	10·71
C	16th February, 1905 ...	10·27
D	17th February, 1905 ...	10·51
E	26th February, 1905 ..	9 94
F	3rd March, 1905 ...	8·01

These figures, representative as they are, indicate that from 15 per cent. to 17 per cent. is about the maximum amount of moisture which jute is likely to absorb under normal circumstances, and no one who has handled jute would have any hesitation in describing a sample of fibre containing more than 18 per cent. of moisture as "damp." It now remains to compare these percentages with the results of actual experiments, and the following further quotations[1] shew the effect of exposing dry samples of fibre to an atmosphere whose temperature and humidity are known :—

"To do this, the sample was placed in the upper perforated shelf of a water oven, the temperature of which was regulated to within a range of about $1\frac{1}{2}$ degrees by a thermostat. Inside the oven also was a wet and dry bulb thermometer, to indicate the degree of saturation of the atmosphere to which the sample was exposed. A small flat dish containing water was placed on the bottom shelf of the oven, so that the moisture absorbed from the air by the fibre might be replenished. The oven had two doors, the inner one being of glass, so that the hygrometer could be read without opening the oven."

TABLE V.

Showing the amount of moisture absorbed by samples of jute fibre from an almost saturated atmosphere at a high temperature.

Experiment	Temperature (degrees Fahrenheit)	Difference between readings of wet and dry bulbs (degrees Fahrenheit)	Approximate percentage humidity of atmosphere in oven	Time of exposure (hours)	Percentage of moisture found in fibre
1	92·0	1·0	96	48	16·70
2	91·0	1·0	96	48	16·23
3	92·0	2·0	94	48	16·66
4	92·3	1·3	94	24	15·26
5	92·0	1·0	96	48	16·35
6	93·0	1 0	96	48	16·82
7	94·0	1·2	95	67	17·28
8	93·0	0·5	98	144	17·65
9	93·0	1·0	96	96	16·65
10	94·0	0·5	98	144	17·50

[1] *Loc. cit.*

It thus appears that, after exposure for a time varying from 24 hours to 144 hours (1—6 days) in an atmosphere whose temperature is over 90° F. (32·5° C.) and whose percentage humidity is over 95, jute fibre absorbs less than 18 per cent. of water. These conditions approximate to—they are, if anything, damper on the whole than—the average of those prevailing, for any such prolonged period as four days, even in the rainy season, in India.

In the course of the years following the publication of the above figures, other work on the same lines has been carried out as opportunity offered. The latter results are about to be published in a separate note; but those of them which refer to jute are included here for the sake of completeness.

It has been seen that, in the early experiments, the fibre was exposed to an atmosphere which was approximately saturated with moisture vapour; nevertheless conditions of absolute saturation were never obtained. The first experiments, as has already been stated, were carried out in a jacketted oven with double doors. Later a Hearson's cool incubator was used, and water in flat-bottomed dishes and screens of wetted filter paper were introduced, to aid the saturation of the atmosphere as far as possible. Even these measures did not produce a completely saturated atmosphere as the following copy of a record card indicates :—

TABLE VI.

Jute.

Date	Hour	Dry bulb	Wet bulb	Difference	Relative humidity
10th May, 1908 ...	10 A.M.	...	...	...	...
Ditto ...	10·30 A.M.	75·7° F.	74·0° F.	1·7° F.	92·5 per cent.
Ditto ...	4 P.M.	75·5° F.	74·3° F.	1·2° F.	94·5 ,,
11th May, 1908 ...	7·30 A.M.	74·9° F.	74·2° F.	0·7° F.	97·0 ,,
Ditto ...	2 P.M.	75·7° F.	75·0° F.	0·7° F.	97·0 ,,
Ditto ...	10 P.M.	75·1° F.	74·5° F.	0·6° F.	97·4 ,,
12th May, 1908 ...	10 A.M.	75·4° F.	74·8° F.	0·6° F.	97·4 ,,
Ditto ...	9 P.M.	75·0° F.	74·4° F.	0·6° F.	97·4 ,,
13th May, 1908 ...	10 A.M.	75·4° F.	74·8° F.	0·6° F.	97·4 ,,
Ditto ...	11 A.M.	Samples taken out.			

In this case there were six samples of fibre weighing from 2·5 grm. to 4·7 grm., and the respective moisture contents after exposure as above were :—

(*a*) 23·02 per cent.
(*b*) 22·39 ,,
(*c*) 22·69 ,,
(*d*) 22·85 per cent.
(*e*) 23·07 ,,
(*f*) 22·86 ,,

i.e., mean absorption of water vapour after 3 days' exposure to an atmosphere whose temperature was 75° F. (24° C. approximately) and whose relative humidity was 97·5 per cent. .. 22·81 per cent.

Similar experiments at the same temperature, but for longer periods, gave absorption figures as follows :—

TABLE VII.

Mean absorption of water vapour after 6 days .. 24·43 per cent.
Ditto ditto 12 days .. 24·95 „

In more recent experiments, detailed below, the following procedure was adopted to secure a saturated atmosphere at a constant temperature. About 2 grm. of the fibre was placed in a small beaker, which was put in a wide-mouth glass-stoppered bottle containing a little water. The bottle was closed and kept in a Hearson's incubator at constant temperature. It is assumed that saturated conditions were realized in this way, but though decidedly higher results have been obtained for longer periods, short exposures do not seem to have produced materially greater absorption than before.

The following copy of a record card shows the variations of the side thermometer in the incubator.

TABLE VIII.

Jute, 7 bottles.

Each sample weighed approximately 2 grm.

Date	Time	Temperature		Remarks
		Centigrade	Fahrenheit	
11th July, 1916 ..	4·30 P.M.	23·00°	73·40°	Samples put in.
12th July, 1916 ..	7·40 A.M.	23·00°	73·40°	One sample taken out.
13th July, 1916 ..	7·30 A.M.	23·00°	73·40°	Ditto.
14th July, 1916 ...	7·20 A.M.	23·25°	73·85°	One sample taken out, during which temperature rose to 23·75° C.
Ditto	9·45 A.M.	23·75°	74·75°	
15th July, 1916 ...	7·30 A.M.	23·25°	73·85°	One sample taken out.
Ditto	4 P.M.	23·50°	74·30°	Temperature constant all day.
16th July, 1916 ...	7 A.M.	23·25°	73·85°	One sample taken out.
Ditto	3 P.M.	23·00°	73·40°	Ditto
17th July, 1916 ...	7·30 A.M.	23·25°	73·85°	Ditto
18th July, 1916 ...	7·30 A.M.	23·25°	73·85°	Ditto

The respective moisture contents of the samples, taken out each day during the progress of the experiment just described, were as follows :—

TABLE IX.

Temperature 23° C. (73·40° F.)

Time of exposure	Percentage of moisture found
Original sample	13·5 per cent.
13 hours	17·7 ,,
37 ,, (1½ days)	21·1 ,,
61 ,, (2½ ,,)	21·8 ,,
105 ,, (4½ ,,)	23·4 ,,
139 ,, (5½ ,,)	25·6 ,,
163 ,, (6½ ,,)	25·8 ,,
187 ,, (7½ ,,)	27·0 ,,

These figures show a distinct increase in the amounts of water absorbed by the fibre from a saturated atmosphere, as compared with one which is not quite saturated.

Experiments were carried out with similar weights of fibre, *viz.*, 2 grm. approximately, at different temperatures ranging from 16° C. (60° F.) to 36° C. (96·8° F.); and the respective results for these latter temperatures are given below:—

TABLE X.

TEMPERATURE 16° C. (60° F.)		TEMPERATURE 36° C. (96·8° F.)	
Time of exposure	Percentage of moisture found	Time of exposure	Percentage of moisture found
Original sample ...	12·7 per cent.	Original sample ...	13·0 per cent.
12 hours (½ day) ...	16·5 ,,	1 day .	22·2 ,,
26 ,, (1½ days)	19·0 ,,	2 days ...	24·4 ,,
60 ,, (2½ ,,) ...	20·2 ,,	3 ,, ...	26·6 ,,
84 ,, (3½ ,,)	21·9 ,,	4 ,, ...	27·2 ,,
132 ,, (5½ ,,) ..	25·8 ,,	5 ,, ..	27·9 ,,
180 ,, (7½ ,,) ...	.....	6 ,, ...	27·8 ,,
204 ,, (8½ ,,) ...	26·1 per cent.	....	.....

The following results with larger quantities of fibre are interesting: none of the weights is large, yet it seems that the bulk of the fibre, represented by half an ounce weight (15 grm.), has not absorbed its maximum proportion of water vapour even after 6 days.

TABLE XI.

Temperature 19°—20° C. (68° F.)

Weight of sample in grm.	Time of exposure	Percentage of moisture absorbed
1·9712	6 days	26·4 per cent.
2·3438	,,	26·0 ,,
2·7454	,,	25·2 ,,
15·9320	,,	20·8 ,,
17·6820	,,	20·6 ,,

DISCUSSION OF RESULTS.

Taken together, the above results furnish sufficient data to discuss the possibility of "heart damage" occurring in jute, which has obtained its moisture in a legitimate way only, *viz.*, by absorption from a damp atmosphere.

The figures are very concordant, and they show that, at a temperature of 36° C. (96·8° F.) and in a completely saturated atmosphere, the maximum absorptive capacity of jute fibre for water vapour is less than 28 per cent.; at lower temperatures (23° C. and 16° C.), it would seem to be slightly, but actually and proportionately, less, and it is interesting to note that the absorption seems to be more rapid at the higher temperatures than at lower ones.

Graphic representation of the results for all three temperatures is given in the accompanying set of curves.

The baling tests described in the first part of this note indicate that about 25 per cent. of moisture is sufficient to allow the development of "heart damage" in jute. At first sight, therefore, the fact that the fibre is, under certain conditions, actually capable of absorbing more than this amount of moisture vapour, seems to indicate that "heart damage" may sometimes be caused by natural moisture. Reflection, however, reminds us, firstly, that the atmospheric conditions under which jute fibre can absorb 25 per cent. of moisture are those of absolute saturation; and, secondly, that even in such a constantly saturated atmosphere, over four days are required for the absorption of 25 per cent. We are further reminded that if the humidity conditions fall short of saturation by even so much as 2 or 3 per cent., the absorption capacity of the fibre falls well below the minimum of 25 per cent. necessary for the production of "heart damage" even after 6 days' exposure.

ABSORPTION OF MOISTURE BY JUTE
IN A SATURATED ATMOSPHERE.
DAYS
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.5
DAYS
16°C.
23°C.
36°C.
5
10
15
20
25
30
PERCENTAGES OF MOISTURE

Remembering these facts, and bearing in mind also not only how comparatively rare it is for conditions of absolute saturation to prevail at all; but also how unprecedented would be the meteorological conditions which would induce constant saturation for a period of four days, we see how improbable it is that any genuine sample of fibre would be found containing even so much as 20 per cent. of moisture, let alone 25 per cent. This view is supported by the results detailed in Table V. They show that no sample absorbed as much as 18 per cent. of moisture after four days in a closed vessel, whose atmosphere was about 95 per cent. saturated. It has already been pointed out that such conditions approximate to (they are, if anything, decidedly damper than) the average of those prevailing for any such prolonged period as four days in the rainy season in India.

It is difficult, even in the laboratory, to secure absolute saturation, excepting in so confined a space as a tightly corked bottle, or its equivalent, and it is still more difficult to maintain such conditions over any long period. It is certain that such conditions never exist in places where jute is stored.

The contents of Table X are important in this connection. They show that unless the quantity of the fibre is very small, and also very loosely packed, the interior of the bulk of fibre cannot absorb a maximum amount of water vapour in a reasonable time. Even so small a quantity as half an ounce (15 grm.) only absorbed 20 per cent. of moisture from a saturated atmosphere in 6 days, as compared with 26 per cent. taken in by the smaller bulk of 2 grm. Such results prove that, even in a saturated atmosphere, provided considerable condensation does not take place, the passage of moisture into the interior of any large bulk of fibre, loose or baled, would proceed only slowly. Thus even if a thin outer layer absorbed the maximum amount of moisture, the average moisture contents of the whole bulk would still be only slightly affected.

The conclusion is therefore inevitably reached that it is virtually impossible for genuine dry jute, either loose or after baling, to absorb sufficient moisture vapour from the atmosphere to allow of the development of "heart damage."

Table XI is further interesting in connection with the question of "ship damage" (pp. 43 & 44).

"Ship damage" is well known and is the cause of numerous disputes and arbitrations between shippers in India and importers in Europe. The result of its action on jute is the same as that of "heart damage," and both are

probably produced by the same organism. Both forms of deterioration are due to excessive water, but it is generally recognized that "heart damage" commences in the centre of the bale, and that it only takes place when the fibre is unduly damp at the time of baling. On the other hand, dampness of the fibre at the time of baling is not a necessary condition for the production of "ship damage": indeed it is commonly held that, given insufficient ventilation during sea transit, even perfectly sound jute may suffer "ship damage." It has been shown (*vide* 2nd series of *pucca* baling tests, page 44), that the water absorbed during temporary immersion of a bale of dry jute was sufficient to bring the average moisture content of the fibre in the bale to 25 per cent., the approximate minimum moisture percentage necessary for the production of "heart damage" in the centre of the bale. Nevertheless the water did not penetrate to the centre of the bale, which was dry and sound after 6 weeks. On the other hand, the fibre in the outer 2 or 3 inches of the bale had lost all tensile strength. This is "ship damage."

Table XI shows us that moisture vapour takes much longer to penetrate to the centre of even a small bulk of jute, than to be absorbed by a loosely spread layer of fibre; and so long as actual condensation does not take place, its absorption beyond the outer layer of a large quantity of fibre, such as a bale, would proceed only slowly. Nevertheless, if the space were confined and the atmosphere saturated, as in a closed bottle with water at the bottom (*vide* page 54), or, on a large scale, in the hold of a ship, which is not dry and also imperfectly ventilated, the absorption of moisture by bales of fibre in the hold would always increase, even though the fibre does not come into actual contact with water in the hold. Ultimately the moisture might accumulate sufficiently in, and penetrate deeply enough into, some of the bales to cause decay of the outer layers of fibre. This again is "ship damage."

In the hold of a damp and badly ventilated ship, continual evaporation of water during the heat of the day tends towards constant saturation of the air in the hold with moisture. A part of this moisture would, as shown above, be absorbed, as vapour, by fibre in the hold; but diurnal or climatic changes of temperature would also involve more or less frequent condensation of moisture on the surface of some of the bales. In such circumstances the rate of penetration of moisture into the interior of a bale would be more rapid than could be induced by mere absorption of water vapour from a moist atmosphere; moreover, the greater the number of condensations, the more rapid would be the penetration, and consequently the incidence of "ship damage." Ultimately the condition of a bale subjected to such treatment would probably approximate to that of

bale No. 6, already referred to (*vide* pages 43 & 44), which was immersed in water. In all this we have a reasonable explanation of "ship damage" and of the widely held opinion that the conditions existing in the hold of the ship during transit to Europe are connected with its occurrence. The latter opinion is supported by the fact that shipping lines differ considerably in their respective reputations in regard to the percentage of sound bales which they deliver. It is possible, however, that such a reputation may be partly due to other factors, besides careful use of the ventilators during the voyage ; for instance, the efficiency of ventilation is certainly affected by the method of stowing of the bales in the hold of the ship, and it is held that carelessness, or ignorance, in this matter may render good ventilation impossible. On the other hand, it must obviously be more difficult to ventilate properly a hold containing damp jute ; and it is also reasonable to suppose that if sound dry jute is stowed alongside of damp jute, the former will be more liable to suffer " ship damage " than if the hold only contains dry fibre.

PART IV.—SUMMARY.

(1) " Heart damage " is so called because it appears first in the centre of the mass of fibre in which it occurs.

(2) Dry jute never suffers " heart damage " ; but when damp jute is baled, a rise of temperature up to a maximum of about 40° C. (104° F.) takes place in the interior of the bale. This is due to the action of thermophilic bacteria which attack the cellulose constituent of the fibre and apparently hydrolyse it. The result is that a large proportion—sometimes approaching 60 per cent.—of such damaged fibre becomes soluble in water, or in dilute acid, or alkali. The fibre also loses all tensile strength and becomes useless for spinning.

(3) Bacterial cultures have been isolated, which produce the typical characteristics of " heart damage " in the laboratory.

A mould, identified by Dr. Butler, Imperial Mycologist, as *Aspergillus fumigatus*, has been found in practically every bale of " heart damaged " jute examined. The mould has apparently nothing to do with the production of the damage, but lives on the degradation products of the cellulose. Dr. Butler reports that the mould has pathogenic properties and that it has been known to cause deafness in man, as well as a disease of the lungs similar to phthisis. Those who are in the habit of baling damp jute would do well to bear this fact in mind.

(4) The more tightly the fibre is packed, *i.e.*, the greater the pressure employed, the lower the proportion of water required for the development of " heart damage " is. Thus small masses of loose jute will probably not suffer damage with less than 45 per cent. to 50 per cent. of moisture.

It has been ascertained by actual experiment that *kutcha* bales (3½ maunds or about 280 lb.) require over 30 per cent., but that *pucca* bales (5 maunds or 400 lb. approximately), which are subjected to a pressure of 2 tons to the square inch, will develop damage with only about 25 per cent. water.

In this connection it is interesting to note that, at the pressure used in making *pucca* bales, fibre containing 25 per cent. of moisture just begins to

exude a little water. Below this figure no water is squeezed out by the pressure.

Percentages of moisture are estimated by drying the damp fibre to constant weight in an oven at a temperature of about 105° C. (221° F.)

(5) Jute exposed for 100 hours to conditions considerably more favourable than an average for those prevailing during the rainy season in Bengal, *viz.*, a temperature of 33° C. (92° F.) and a humidity of about 95 per cent., absorbed a maximum of 17·5 per cent. of moisture. This is 7½ per cent. below the minimum required for the development of " heart damage " in *pucca* bales.

(6) Jute fibre can be made to absorb about 27 per cent. of moisture, but only in a reasonable time when in very small quantities, or in thin layers loosely spread, and when the atmosphere is completely saturated with water vapour. Even under these favourable conditions a period of about four days (100 hours) is required for the absorption of 25 per cent. moisture.

(7) Such a combination of conditions never occurs in practice, and the incidence of " heart damage " in genuine jute may be regarded as impossible.

Fibre which has been improperly dried after extraction, or which has been exposed to night dews, or otherwise watered, is not regarded as " genuine."

(8) " Ship damage " of baled jute is similar in its effects to " heart damage" and is probably produced by the same class of organisms. " Ship damage ", however, appears first in the outside layers of the bale and not in the interior of it as happens with " heart damage."

It is tentatively shown how bales of sound dry jute stowed in a damp and badly ventilated ship's hold might absorb sufficient water, through repeated condensations of moisture from the air, to enable " ship damage " to ensue.

DACCA :
3*rd July* 1917.

APPENDIX I.

(*a*) Reports, and a note, by Dr. Butler, Imperial Mycologist, Pusa, on Aspergillus fumigatus, Fres.

No. 60 of 1917-18.

From

Dr. E. J. Butler, m.b., f.l.s.,

Imperial Mycologist, Agricultural Research Institute, Pusa,

To

The Fibre Expert to the Government of Bengal, Dacca.

Dated Pusa, Bihar, the 7th May, 1917.

Sir,

I have the honour to report that I have received the culture of a mould from damaged jute, sent with your letter dated 28th April, 1917, in good condition.

The fungus is *Aspergillus fumigatus*, Fresenius, a cosmopolitan species common on plant remains and industrial products, especially under conditions of high temperature, and also not rare as a parasite of man and animals (lungs, ear, etc.).

The optimum temperature of this fungus is from 37° to 40° C., so that it may be expected to appear where fermentation has led to heating in the bales.

I have the honour to be,

Sir,

Your most obedient servant,

(Sd.) E. J. Butler,

Imperial Mycologist.

No. 74 of 1917.

From

Dr. E. J. Butler, m.b., f.l.s.,

Imperial Mycologist, Agricultural Research Institute, Pusa,

To

The Fibre Expert to the Government of Bengal,

Government Farm, Dacca.

Dated Pusa, Bihar, the 12th May, 1917.

Sir,

I have the honour to report, in continuation of my letter No. 60, dated the 7th May, 1917, that the incubation tests with the mould from damaged jute have confirmed the identification of the fungus as *Aspergillus fumigatus*, Fres.

It grows much more vigorously at high temperatures, approaching 40° C. (104° F.); scarcely at all at 22° C. (72° F.)

The young cultures are typical in every respect of the species as described in Europe.

As its interest lies in its high optimum temperature and its pathogenicity to man, can you let me know if damaged jute, such as that from which it was taken, heats; and also whether cases of lung or ear disease are reported from the jute mills where such jute is handled ?

I have the honour to be,

Sir,

Your most obedient servant,

(Sd.) E. J. Butler,

Imperial Mycologist.

Note on aspergillus fumigatus, fresenius.

by

E. J. Butler, m.b., f.l.s.

Imperial Mycologist.

Aspergillus fumigatus Fres. is a cosmopolitan mould, first described by Fresenius from the air cavities of a bustard in 1841. It has attracted attention chiefly from its not infrequent occurrence in the body cavities of man and

animals (horse, cow, pigeon, domestic fowl, turkey, etc.), and its proved pathogenicity to many small animals when inoculated into the blood stream or the peritoneal cavity, or by inhalation into the lungs. In man it is best known as an ear parasite, sometimes causing complete deafness. It attacks also the human lung, producing a type of disease often difficult to distinguish, without the aid of the microscope, from phthisis. Less often it has been found in the nasal cavity and on wounded surfaces, especially in the eye. These infections are most commonly observed amongst persons engaged in certain occupations ; those of the lung, for instance, being prevalent amongst the pigeon fatteners and hair combers in Paris.

As a saprophyte it is found on vegetable débris, dead leaves, dry fodder, and on seeds and grains. It has also been obtained from fermenting tobacco leaves ; from potatoes, bread, etc., in warm incubators ; and on woollen fabrics. Recently it has been proved to be a common soil dweller in parts of the United States (Cornell) and it also occurs in the soil at Pusa. It has not previously been reported in India on vegetable matter, no doubt because it has not been looked for, since it is exceedingly unlikely to be confined to jute. But it only attracts notice, as a rule, when it becomes a human parasite, and this is relatively rare except amongst those exposed to repeated infections. The pigeon fatteners of Paris feed their pigeons with seeds and grain from their own mouths, and such seeds and grain often bear spores of the fungus. So also the hair combers use contaminated rye flour for powdering the hair while working at it. It is evident that there is a possible danger to jute mill workers who handle contaminated jute, and enquiries have been instituted to ascertain whether cases of infection have been observed.

The characters of the fungus are as follows : The growth is whitish when young, but rapidly turns light green and then olive or dark green as the spores mature. The mycelium is colourless, the individual threads being 2/1000 to 3/1000 mm. in diameter and not much raised above the surface on which they are growing. As the spores develop the growth becomes more woolly or velvety, and green, at first in patches and then uniformly. The spores are borne on short, unbranched stems, 1/10 to 3/10 mm. in height by about 6/1000 mm. thick, the top being swollen into a club-shaped head, some 15/1000 mm. across. On the upper part of this, a layer of closely crowded, parallel spore-stalks arise, all pointing upwards and each terminating in a chain of spores. The individual spore-stalks are unbranched and shorter than the diameter of the club-shaped head. The spore chains are long and often closely pressed together into a long cylindrical green head. The spores are colourless or faint green singly, round, smooth, and only 2/1000 to 3/1000 mm. in

diameter. A second spore-form, the product of sexual reproduction, has been reported, but it is open to some doubt whether it really belongs to *Aspergillus fumigatus*. In it the spores are borne in little sacs in the manner characteristic of the fungus class *Ascomycetes*. This stage is authentic in several other species of *Aspergillus*.

The species is a lover of heat. It grows best at temperatures of 37° to 40° C., and doubtless this character aids it in its attacks on warm-blooded animals and man. In Pusa it was found scarcely to grow at all at a temperature of 22°.

(*b*) LETTER FROM THE HON'BLE SIR ARCHY BIRKMYRE.

6, Clive Row,

Calcutta, 7th June, 1917.

MY DEAR FINLOW,

I DULY received your D. O. No. 92-H-4 of 25th ultimo. I am sorry that pressure of work has prevented me replying sooner.

I was much interested in the quotation you give from Dr. Butler's letter regarding the results of investigation tests with the mould from damaged jute.

You ask me if I can give you any information, either from my own experience or by reference to the Jute Mills Association, regarding the incidence of pneumonia or ear disease amongst employees in jute mills. Pneumonia is certainly not an uncommon disease amongst jute workers, but I do not think it can be connected in any way with the handling of damaged jute. As a matter of fact, the mills here only use *pucca* bale jute to a very small extent, and I do not think there is any likelihood that "heart damage" would occur in *kutcha* pressed bales as used by the local mills.

It is quite possible that the same results might be obtained from jute which had been packed wet and had rotted as those obtained from mould in "heart damaged" samples, but the extent to which this damage takes place in the local mills is seldom in any considerable volume, and when wet parcels are delivered, they are usually put into consumption at once.

Yours sincerely,

(Sd.) ARCHY BIRKMYRE.

APPENDIX II.

CORRESPONDENCE WITH REPRESENTATIVES OF THE JUTE TRADE IN CALCUTTA ON THE SUBJECT OF "HEART DAMAGE":—

(*a*) Letter from Mr. D. L. Millar (Messrs. D. L. Millar & Co.).

10, Clive Row,

Calcutta, 30th April, 1917.

DEAR SIR,

I HAVE read with much interest the papers you left on Saturday forenoon on the subject of "heart damage" and "ship damage."

The various experiments have been exhaustive and the conclusions sound; these have been gone into so thoroughly that little is left me to remark upon, except to confirm that, so long as jute is shipped sound, there is no fear for the internal condition.

It would be interesting to test the fibre of *C. olitorius* as against *C. capsularis*, the former in both *bogi* and *desi* varieties, as the *olitorius* appears to be able to stand more moisture than the other.

Regarding "ship damage" it is perfectly correct to assume that quite sound dry jute may be "ship damaged" by imperfect ventilation causing condensation, but a good deal depends on the season at which the jute is shipped, and whether sound dry jute is carried in proximity to, or in the same hold as, damp baled jute; where condensation takes place the top tier of bales naturally suffers most and damage is also more likely to take place where contact with beams or stanchions is made.

It is not fair to assume that all "ship damage" is the fault of the ship, it may be partly due to the condition of the jute aggravated by bad ventilation; a well ventilated and properly stowed hold on the other hand might be comparatively free from "ship damage" in similar conditioned jute.

Yours faithfully,

(Sd.) D. L. MILLAR.

(*b*) Letter from Mr. P. E. Suttie (Messrs. Sinclair Murray & Co.).

5-1, Royal Exchange Place,
(Post Box No. 8).
Calcutta, 5th May, 1917.

MY DEAR FINLOW,

WITH many thanks I am returning under registered cover your memorandum on "heart damage" in jute. You know a great deal more about this matter than I do, and, I am afraid, there is nothing I can tell you from experience that would be of any assistance to you. To tell you the truth, I have had very little experience of damage from moisture. In all our places we handle only jute that is comparatively dry; in fact, dry enough to avoid liability to damage.

There is just one point on which I would express an opinion, and that is with reference to Bogi or Tossa jute in comparison to White jute.

On page 14 you say that you found indications that Bogi or Tossa jute was less liable to suffer damage than the White jute fibre; but I think this is not the generally accepted idea in the trade. It is usually considered that Bogi or Tossa will damage much more quickly and to a more serious extent from a certain percentage of moisture than White jute will.

Not long ago I was at one of the mills up the river, when the manager opened in my presence a bale which I understood to be of Tossa or Bogi, and which had gone absolutely rotten, although, so far as the mill people were aware, the moisture contained in the bales, at the time they were received at the mill, had not been considered excessive. This was a *kutcha* bale and, when opened, the jute had the appearance of being undamaged. It was only when one tried to lift a part of it that it was found to crumble into powder. I may mention that the bales in question had been stored in the mill godown for a considerable period, a year or two if I remember rightly.

Also, I know that our people in the mofussil are much more afraid of packing up Bogi or Tossa in a damp state than they are in the case of White jute.

I would suggest that you should make some comparative experiments with Tossa and White jute to satisfy yourself on this point. It could be quite easily done.

There is another point in this connection that I might suggest. We find that on the whole the Tossa contains, or appears to contain, a higher percentage of moisture than White jute does as a rule; but whether this is because more

moisture is added to the Tossa or Bogi, or because the Tossa fibre naturally absorbs moisture more readily than White jute, I am unable to say.[1] It is just possible that Tossa absorbs moisture more readily, because the moistening of jute is, in a great many cases, done under similar circumstances, that is to say, the jute is spread on the ground overnight and allowed to absorb the dew that falls on it during the night. My reason for supposing that Tossa more readily absorbs moisture is that not long ago I was arbitrating on a parcel of jute here in Calcutta. There were 10 bales which were opened for inspection; 9 of the bales were practically dry, in fact dry enough to be passed as in thoroughly good condition; but the tenth bale contained a large percentage of Bogi jute, and the moisture in that bale was decidedly excessive and was, beyond question, due to the presence of Bogi jute in the bale.

Then, there is one other point which I might suggest and about which I spoke to you when you were here last week, and that is that I have always been of opinion that jute, which has been insufficiently dried in preparation, will carry an excess of moisture with less liablity to damage, than jute which has once been thoroughly dried and then wetted.

* * * * * * *

I am,

Yours sincerely,

(Sd.) P. E. SUTTIE.

[1] Experimental observations on this point indicate that White jute (*C. capsularis*) and Tossa or Bogi (*C. olitorius*) differ only very slightly, if at all, in their respective capacities to absorb moisture. [R. S. F.]

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